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High Resolution, Steep Profile, Resist Patterns

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High resolution and steep profile patterns have been generated in a 2.6-μm thick organic layer which conforms to the steps on a wafer surface and is planar on its top. This thick organic layer (a photoresist in the present experiments) is covered with an intermediate layer of SiO_2 and a top, thin layer of X-ray or photoresist. After exposure and development of the top resist layer, the intermediate layer is etched by CHF_3 reactive ion etching. The thick organic layer is then etched by O_2 reactive ion etching. Submicron resolution with essentially vertical walls in the thick organic material was achieved. The technique is also applicable to photo- and electron lithography. It reduces the need for thick resist patterns for the lithography step and, at the same time, ensures high resolution combined with good step coverage.

I. INTRODUCTION

One of the more difficult problems with resist pattern generation is to achieve good linewidth control, high resolution, and good step coverage simultaneously. Often the requirements appear to be mutually exclusive; good step coverage requires thick resist; high resolution, however, is more easily obtained in thin resist. This is true for all resists, both positive and negative.

With any resist, the ideal conditions to obtain high resolution and good linewidth control are a flat surface and a thin resist (3000–4000 A°). The flat surface means that the resist has very little variation in thickness and that, as a result, there will be little variation in resist line width. However, such resist line width variations will occur when lines traverse a step. As device wafers do have steps, thick resist (7000–15000 Å) must be applied to achieve coverage over steps.

We discuss here a method for generating high resolution, steep profile resist patterns by first preparing a flatter surface on the wafer.[1] This is done by applying a layer of thick organic material that conforms with its lower surface to the wafer and is planar on its top. The thick

Table I—High resolution, steep profile, resist patterns

Advantages
1. Planar surface for resist patterning 2. Excellent step coverage 3. Good linewidth control 4. Thinner resist can be used for better resolution 5. Eliminates standing waves and scattering in photolithography 6. Reduces proximity effects in electron lithography 7. Minimal resist erosion during substrate etch by plasma or ions
Disadvantage
Requires extra processing steps

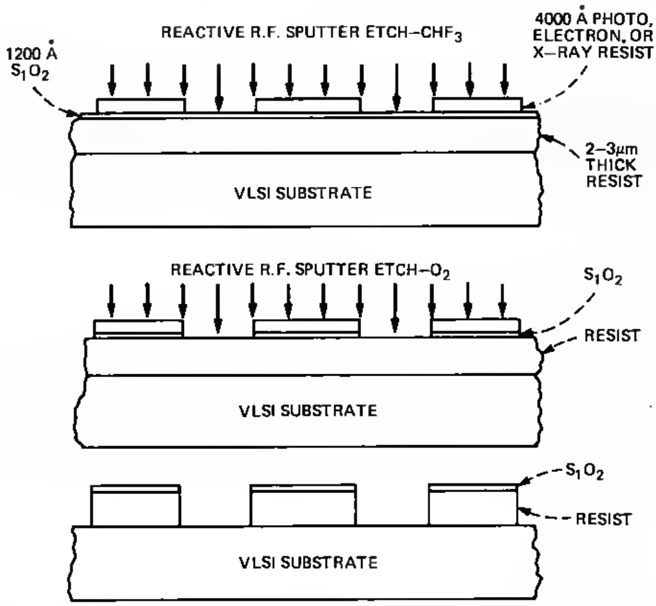

Fig. 1—Schematic presentation of the various steps required to define a steep resist profile.

layer is then patterned using an intermediate masking layer and a thin top layer of X-ray resist. The result is that as much as 2.6 μm of plasma-resistant organic material can be patterned with better than 1-μm resolution and steep sidewalls comparable with those in positive photoresist. The advantages and disadvantages of this technique are outlined in Table I.

II. EXPERIMENT

A 2.6-μm thick layer of photoresist,* serving as the thick organic layer, was spun on a silicon wafer. The intermediate layer of 0.12 μm

* HPR-204, manufactured by Hunt Chemical Co.

of silicon dioxide was plasma-deposited at 200°C on the photoresist, and then a 1.0-μm thick layer of chlorine-based negative X-ray resist was deposited on top of the oxide. Figure 1 is a schematic presentation of the processing sequence.

The top layer of X-ray resist was exposed and developed to a final thickness of 0.45 μm using an X-ray exposure tool.[2,3] With the X-ray resist as a mask, the SiO_2 was either plasma- or reactive-ion-etched with a CHF_3 gas. The pattern was then transferred into the thick organic (resist) layer using reactive RF sputter etching, with pure O_2 gas forming the plasma and the SiO_2 acting as the mask. The RF power density was 0.50 watt/cm^2 and the time required to etch the resist was

Fig. 2—Pattern etching into 2.6-μm thick resist layer using reactive RF sputter etching. Trench width is 1.5 μm.

20 minutes. Figure 2 shows the resultant pattern, which is 2.6 μm high and has a trench width of 1.5 μm. The photos were taken with a scanning electron microscope at a very steep angle to clearly show the wall structure of the resist. Note that the walls are perpendicular and there is very little undercut. The oxide is still on top of the organic (resist) layer, and its thickness loss during the sputter etch was less than 0.02 μm.

Another method of etching the thick organic layer is with plasma etching using a radial flow machine. This method, however, produced patterns with some undercut and had a resist etch uniformity variation across a 3-in. wafer of 50 percent, which, coupled with the undercut, would give poor linewidth control.

Fig. 3—SEM photograph of texture surrounding all the etched features. The fibers of this texture are aluminum oxide and are submicron in diameter.

One of the more serious problems encountered with RF reactive etching was the presence of texture after completion of the etch (see Fig. 3). This texture,[4,5] as determined by Auger analysis, consisted of aluminum oxide fibers that were resistant to further plasma processing. Their formation was due to the presence of aluminum in the active plasma area. In fact, the presence of any metals (e.g., copper, titanium, tantalum, etc.) also produced this texture.

Solution to the texture problem involved the construction of a chamber having no exposed metallic surfaces. Figure 4 shows a pattern etched under these conditions. The thick organic layer in this case is

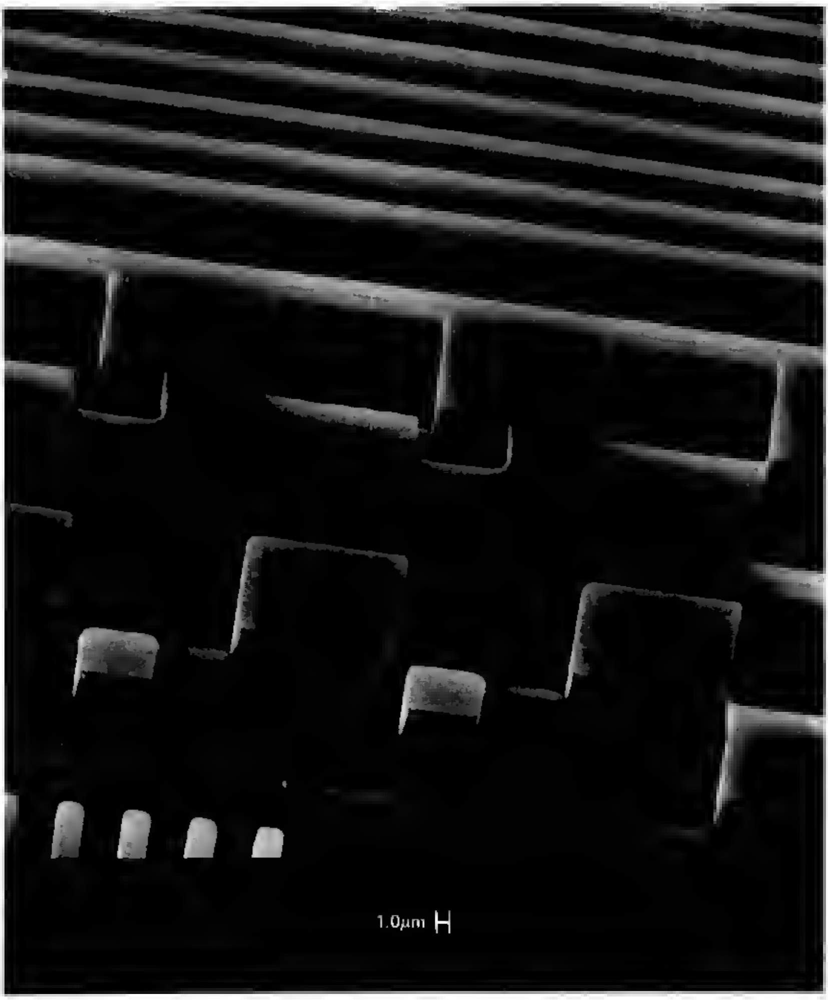

Fig. 4—Pattern sputter-etched using a system having no exposed metallic surfaces. Etching has caused no fiber formation.